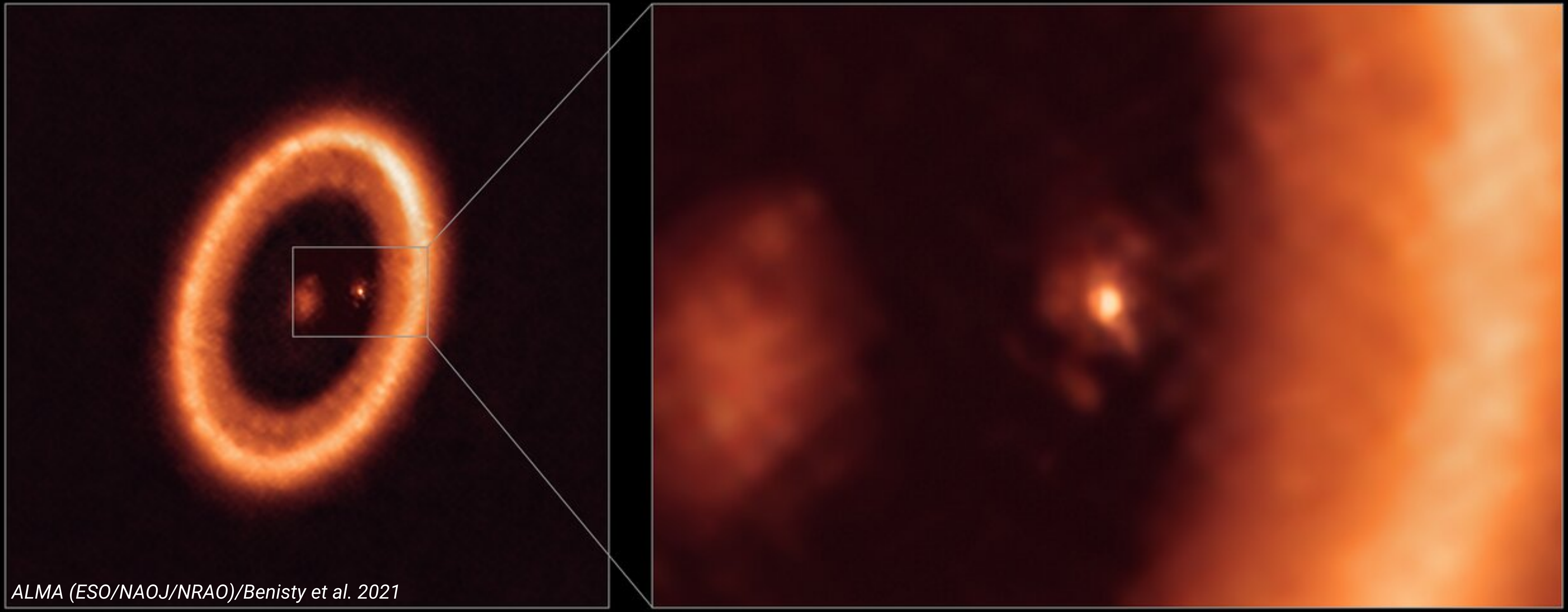
Millimeter-wave Searches for Circumplanetary Material



Sean Andrews
CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

this is not another PDS 70 talk. 😕

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instead, I want to communicate our *failure* to find circumplanetary material in other disks… 😞

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instead, I want to communicate our *failure* to find circumplanetary material in other disks… 😞

…and highlight some prospects and challenges for finding more PDS 70 c's at mm wavelengths. 🧐


giant planet orbits
in the solar system
Andrews et al. 2016, 2018; Huang et al. 2020; Pérez et al. 2019; Dong et al. 2018; ALMA Partnership et al. 2015

substructures ⟹ planets?

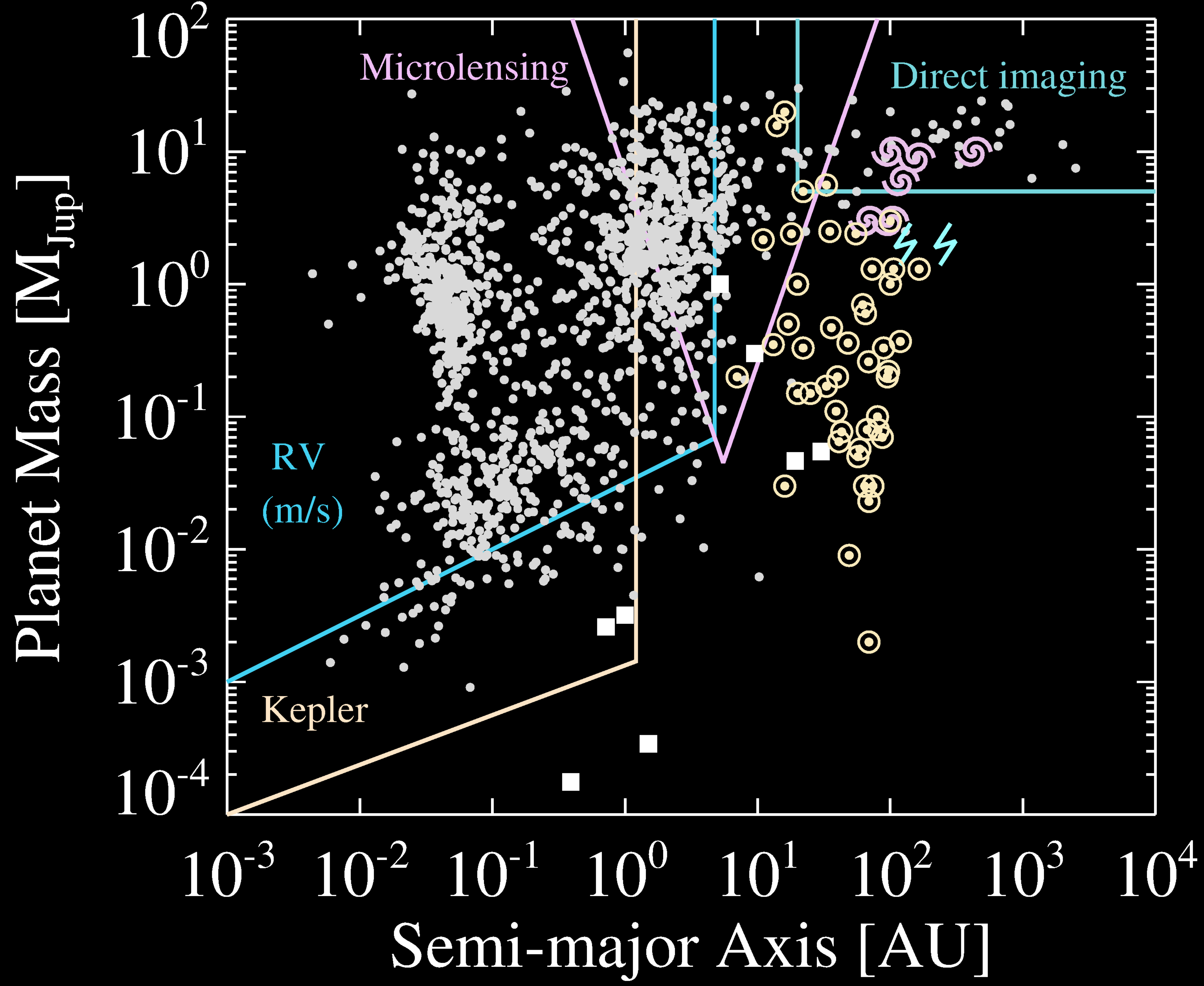

figure and data aggregation by Jaehan Bae

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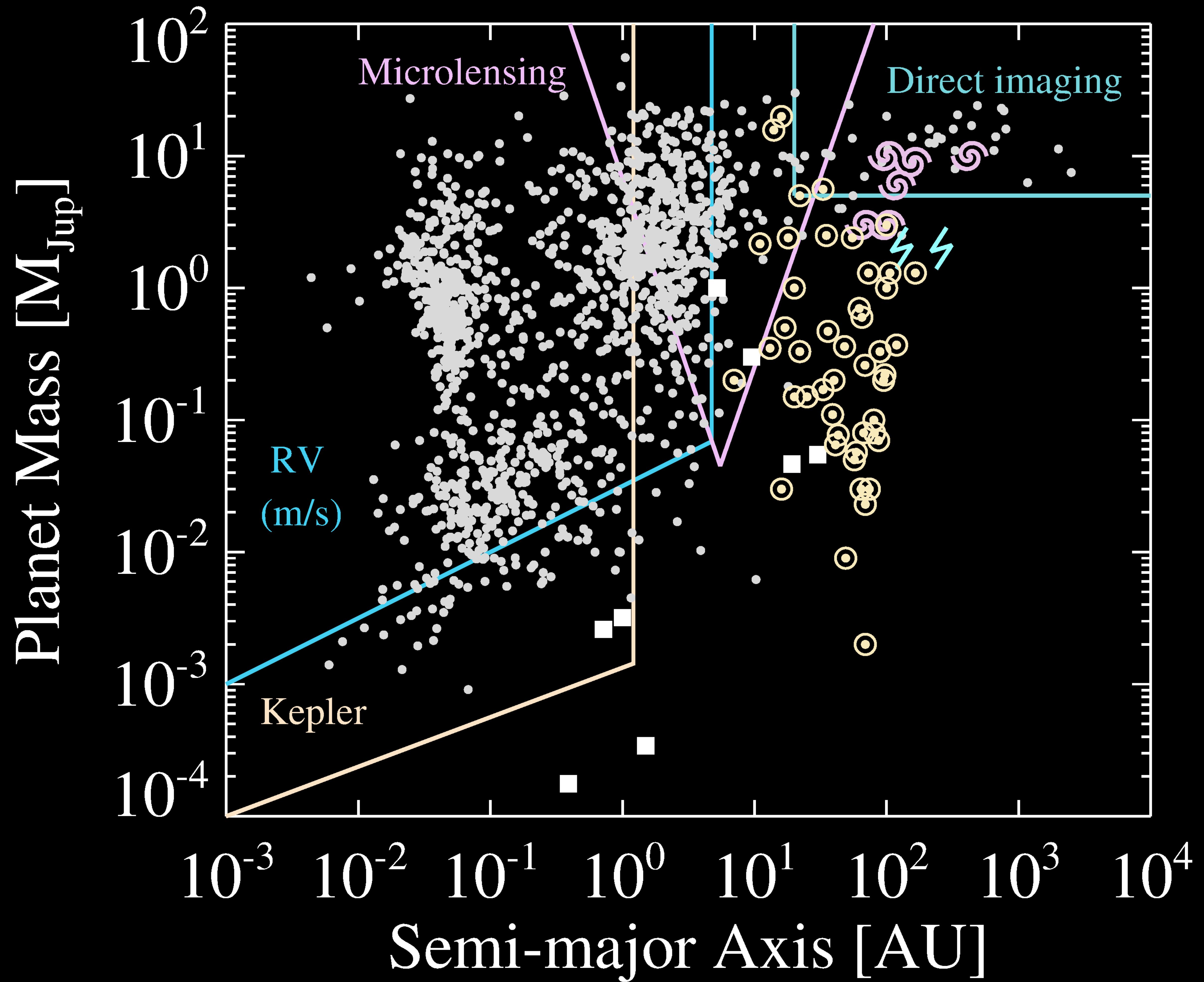


figure and data aggregation by Jaehan Bae

bare photospheres are hard to find

substructures ⟹ planets?

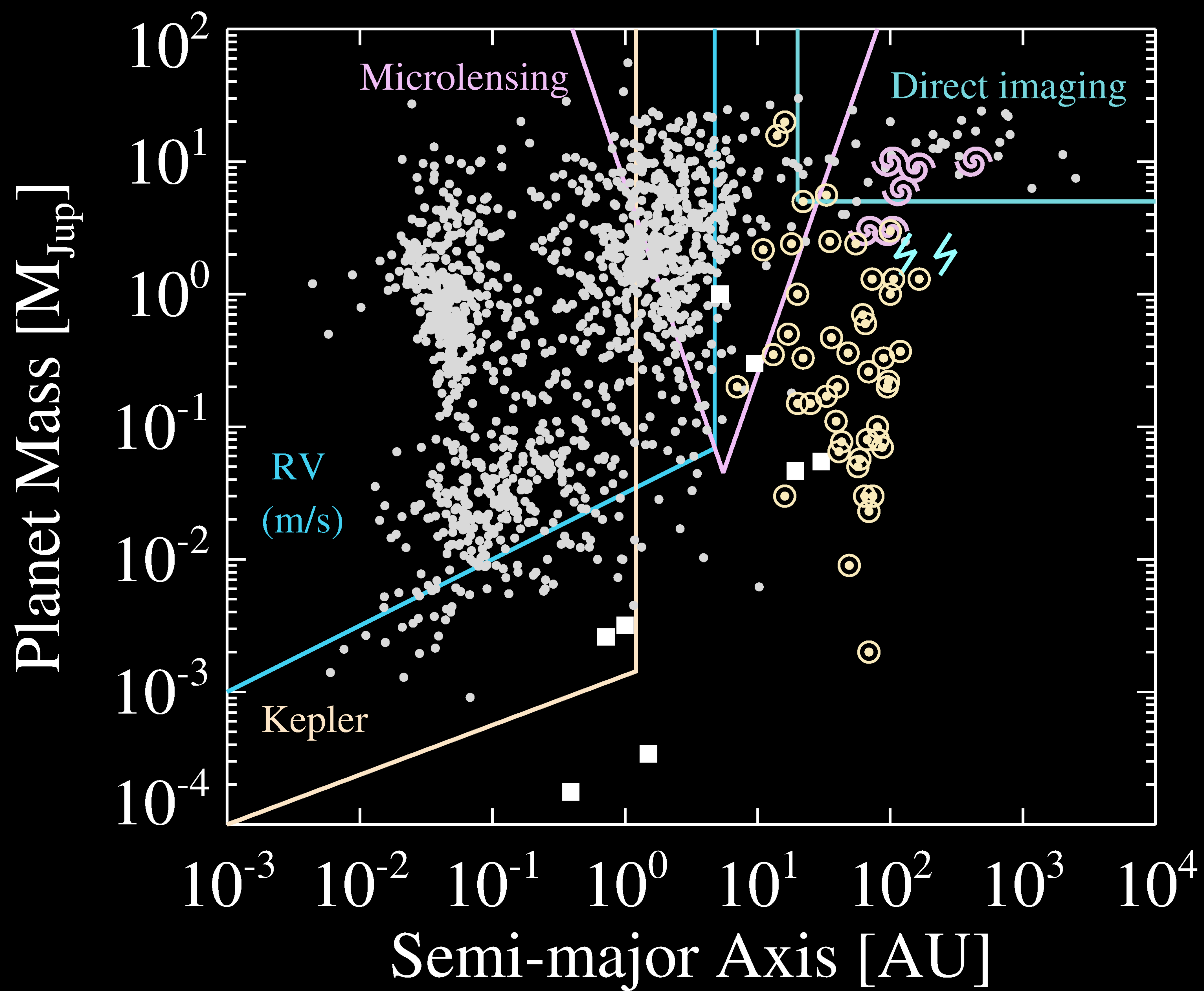
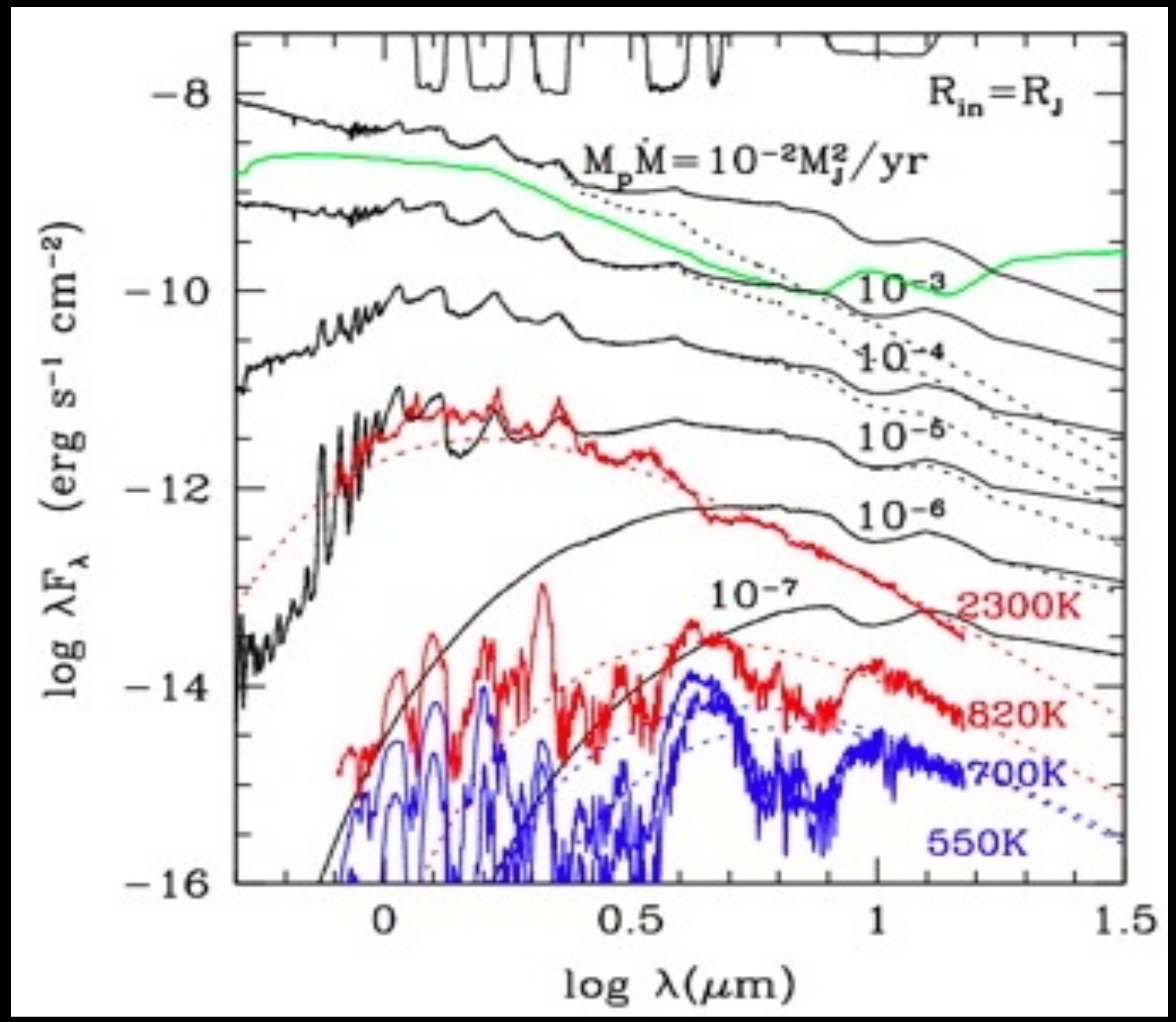


figure and data aggregation by Jaehan Bae

bare photospheres are hard to find

easier to see dusty CPDs!
in the thermal infrared

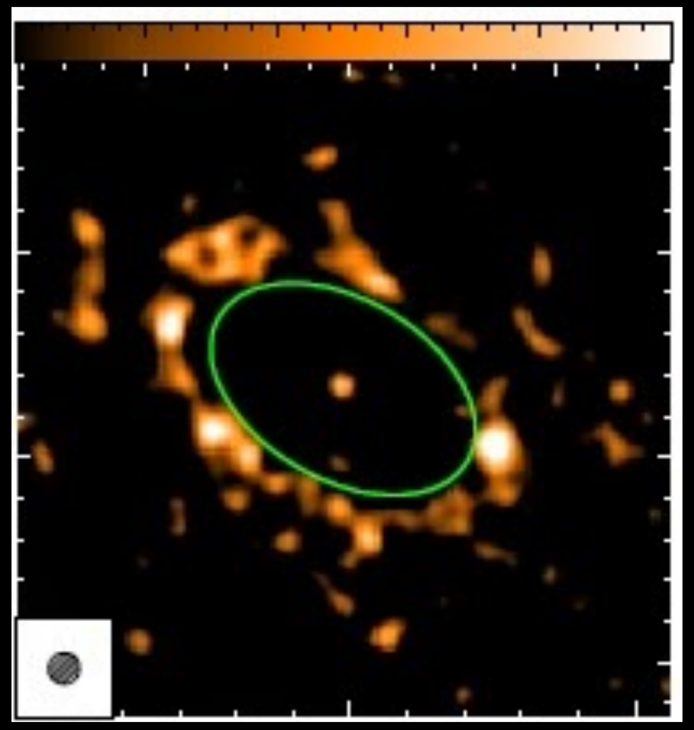


Zhu 2015 (also Eisner 2015; Szulagyi et al. 2018)

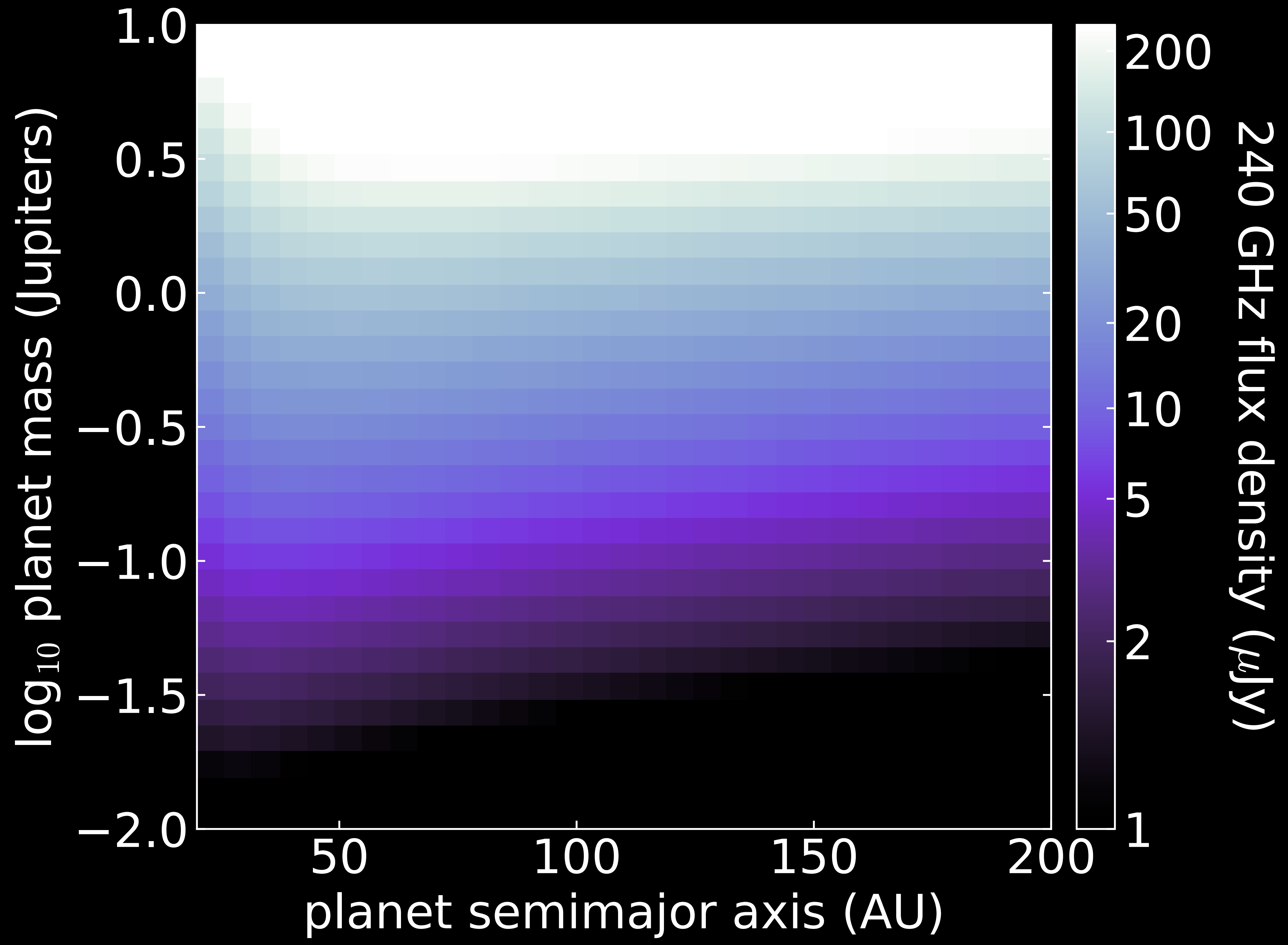
what about measuring CPDs in the (sub-)mm continuum?

advantages:

- no stellar contrast issues
- very good resolution
- (maybe) less extinction (?)
- get satellite mass reservoir



It should be feasible!; e.g.,
Isella et al. 2014
Szulagyi et al. 2018
Zhu, Andrews, & Isella 2018



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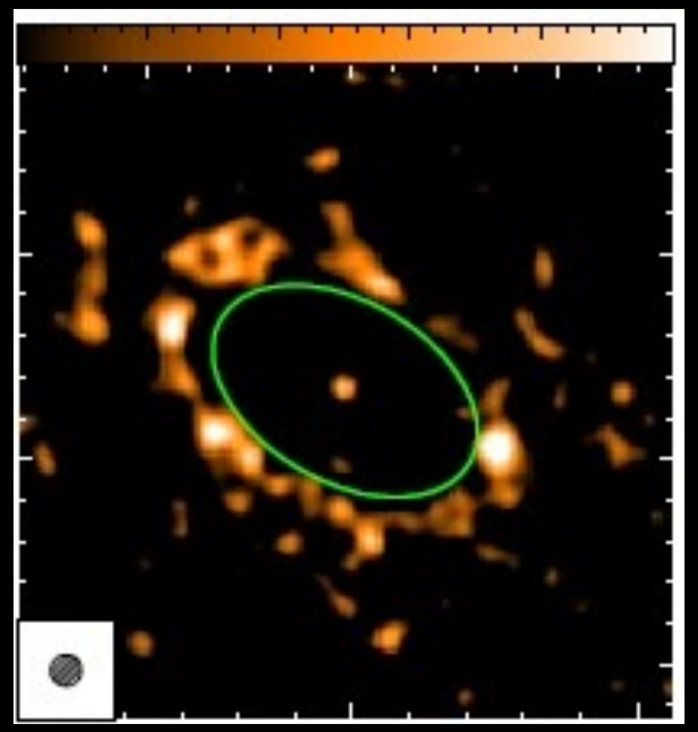

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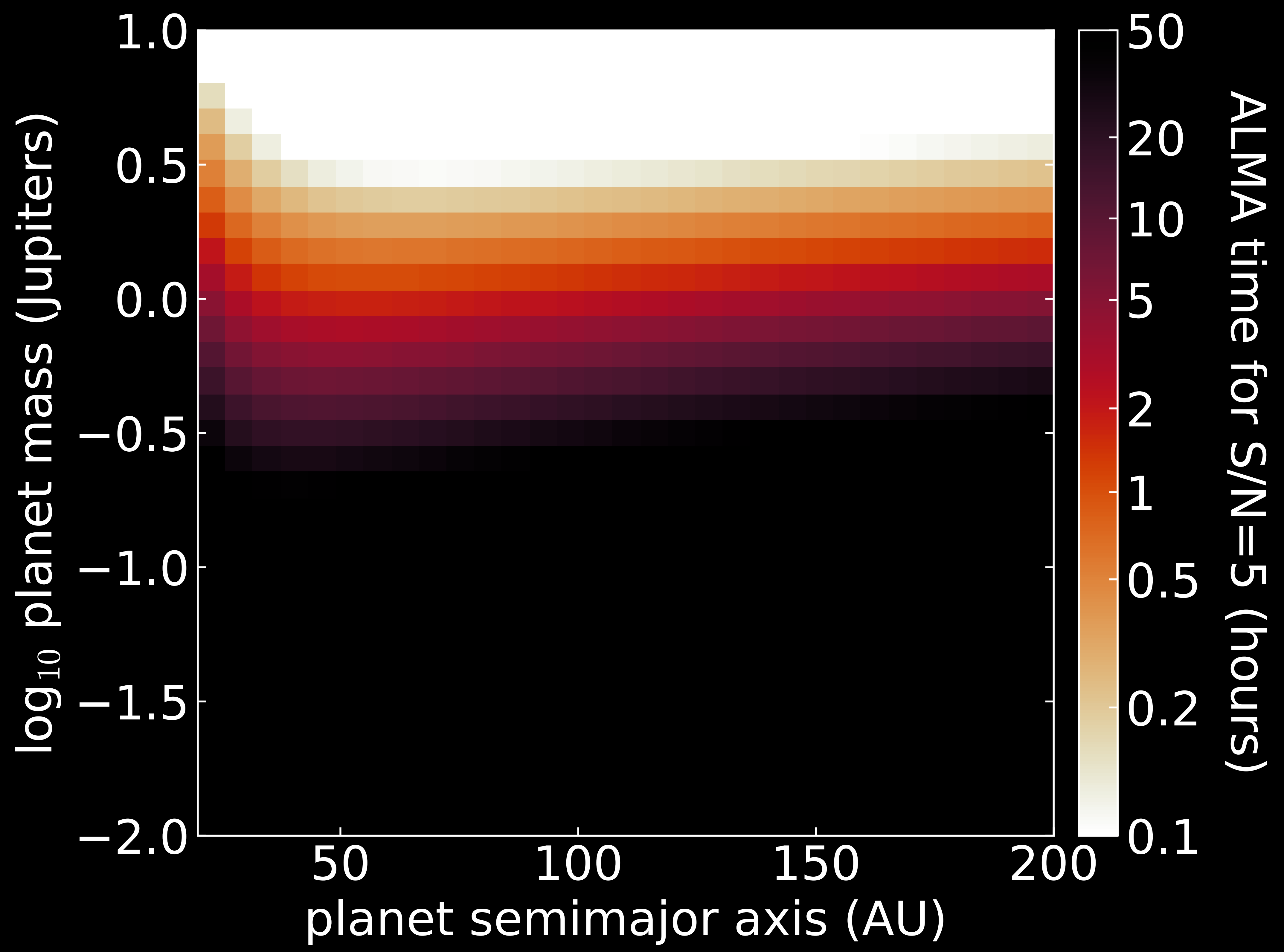
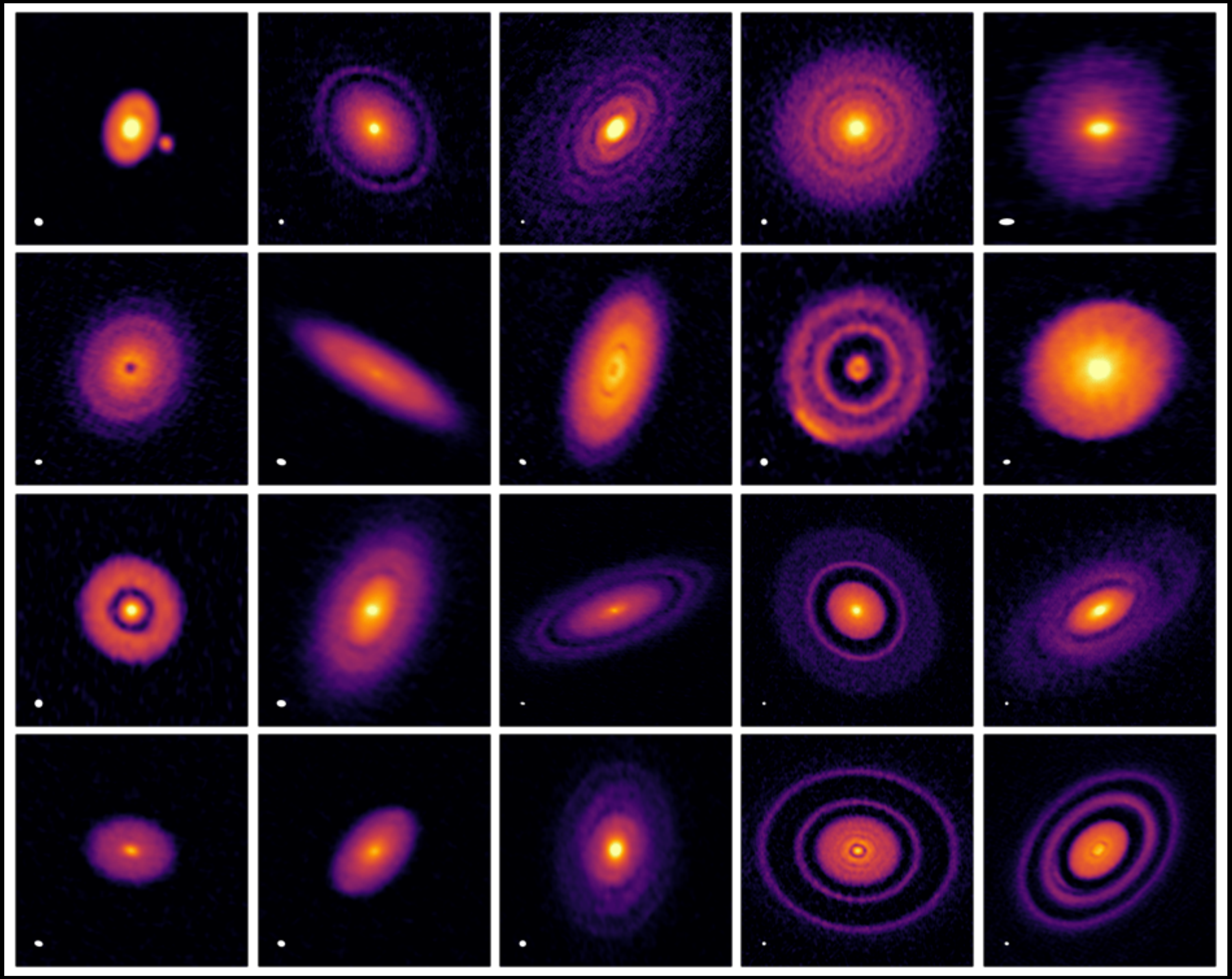
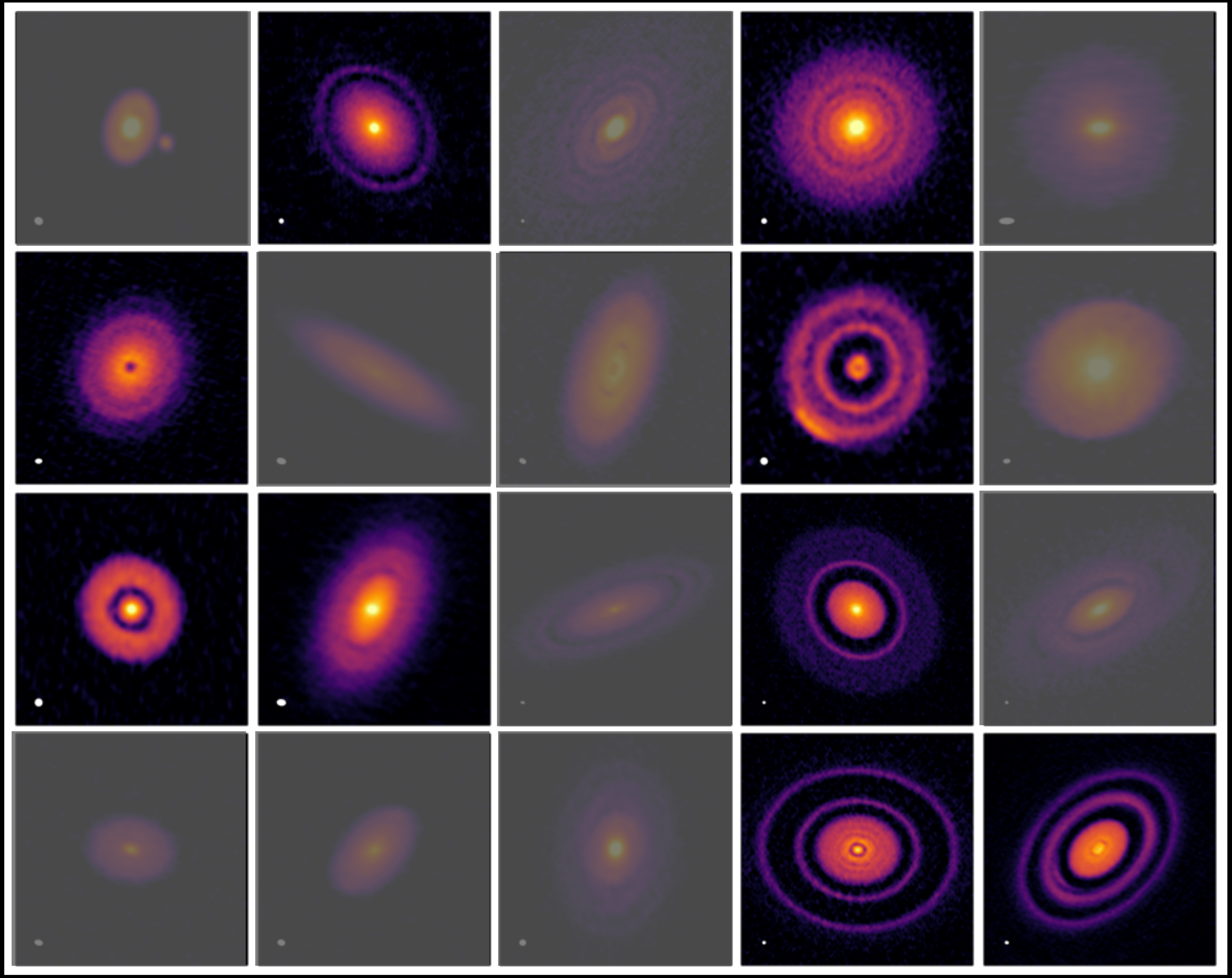




DSHARP: ~30 mas resolution, 10-15 μJy RMS

Andrews et al. 2018

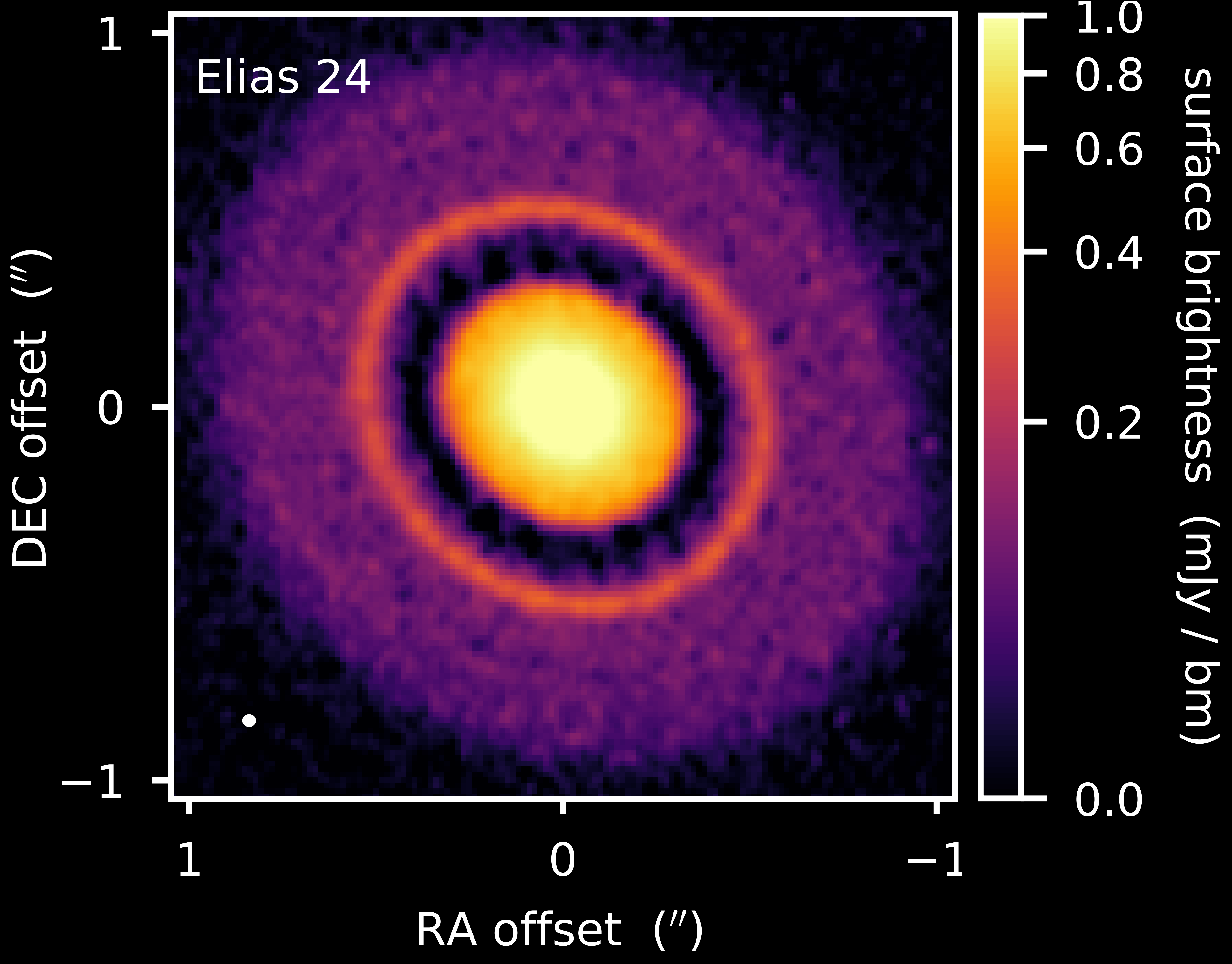


DSHARP: ~30 mas resolution, 10-15 μJy RMS

Andrews et al. 2018

(ignore hard cases)

key challenges: disk confusion and imaging in the noise!



our two-part "solution":

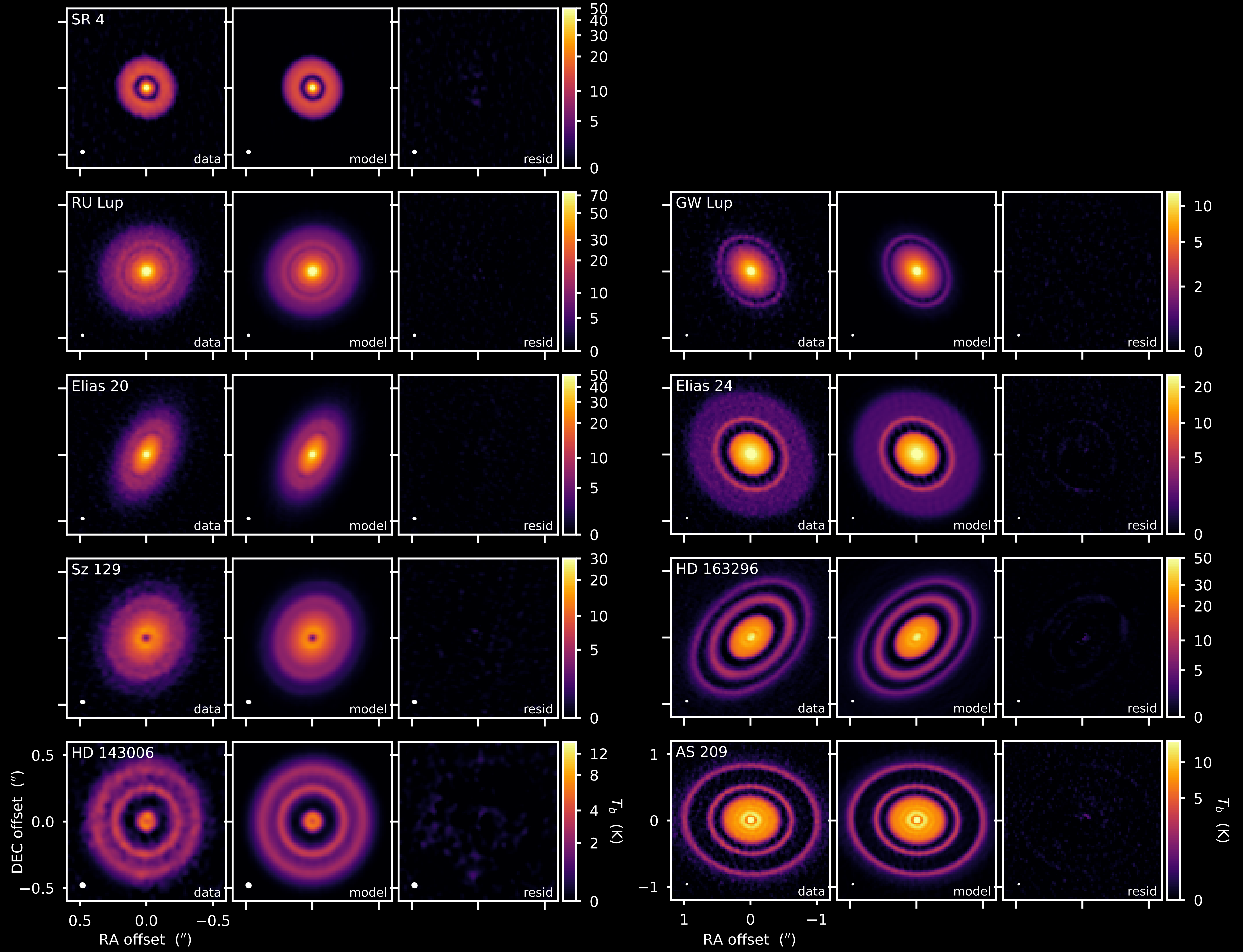
(1) remove disk emission

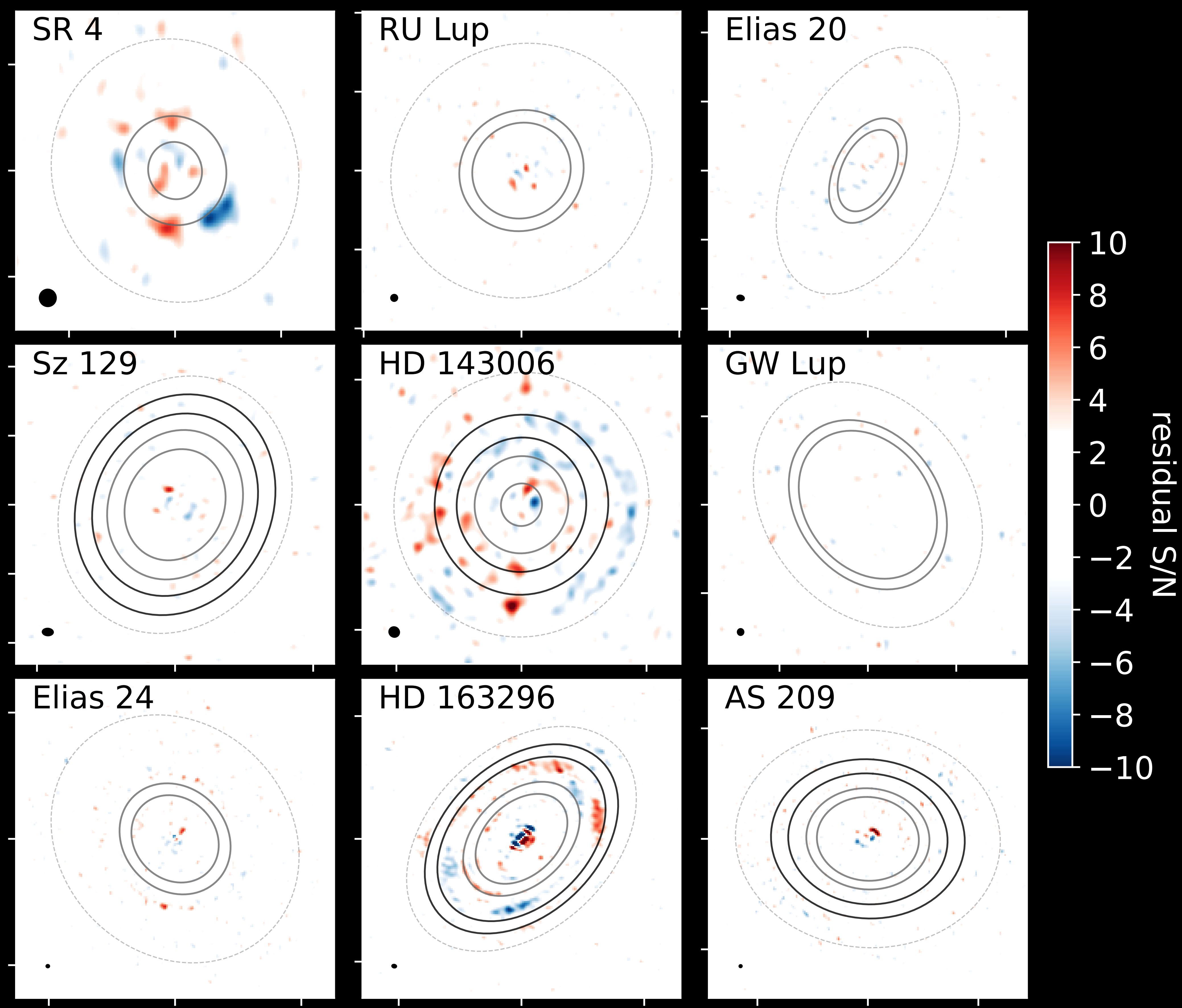
(2) brute-force tests to quantify CPD sensitivity *(injection / recovery)*

(1) remove the (circumstellar) disk emission

"easy"; use frank

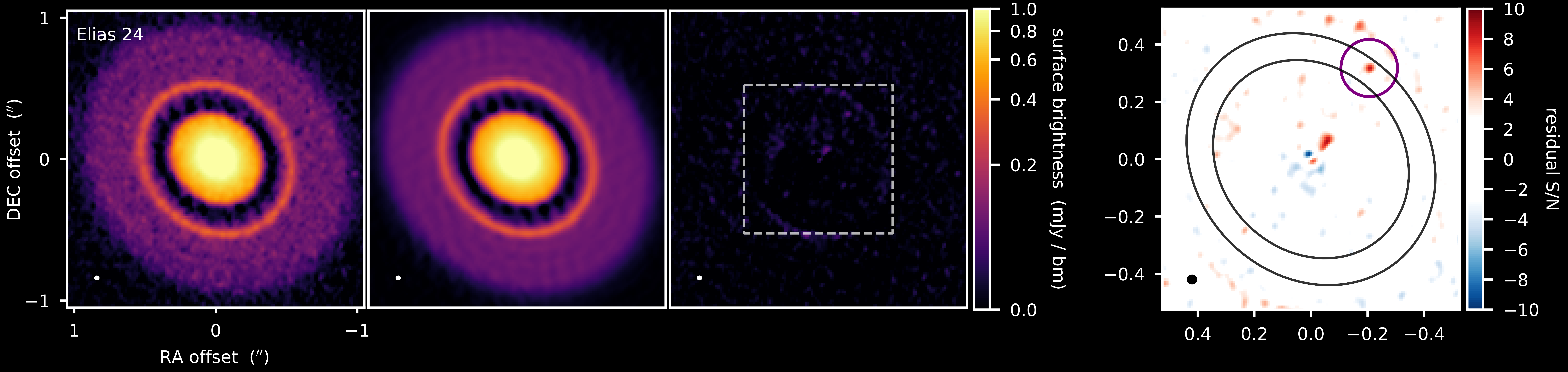
Jennings et al. 2020, 2021





Andrews et al. 2021

(2) quantify CPD sensitivity (injection/recovery tests)



a) inject point source in gap into observed visibilities

b) model those modified visibilities w/ frank

c) image the residual visibilities

d) find peak in gap; compare location/flux to known inputs

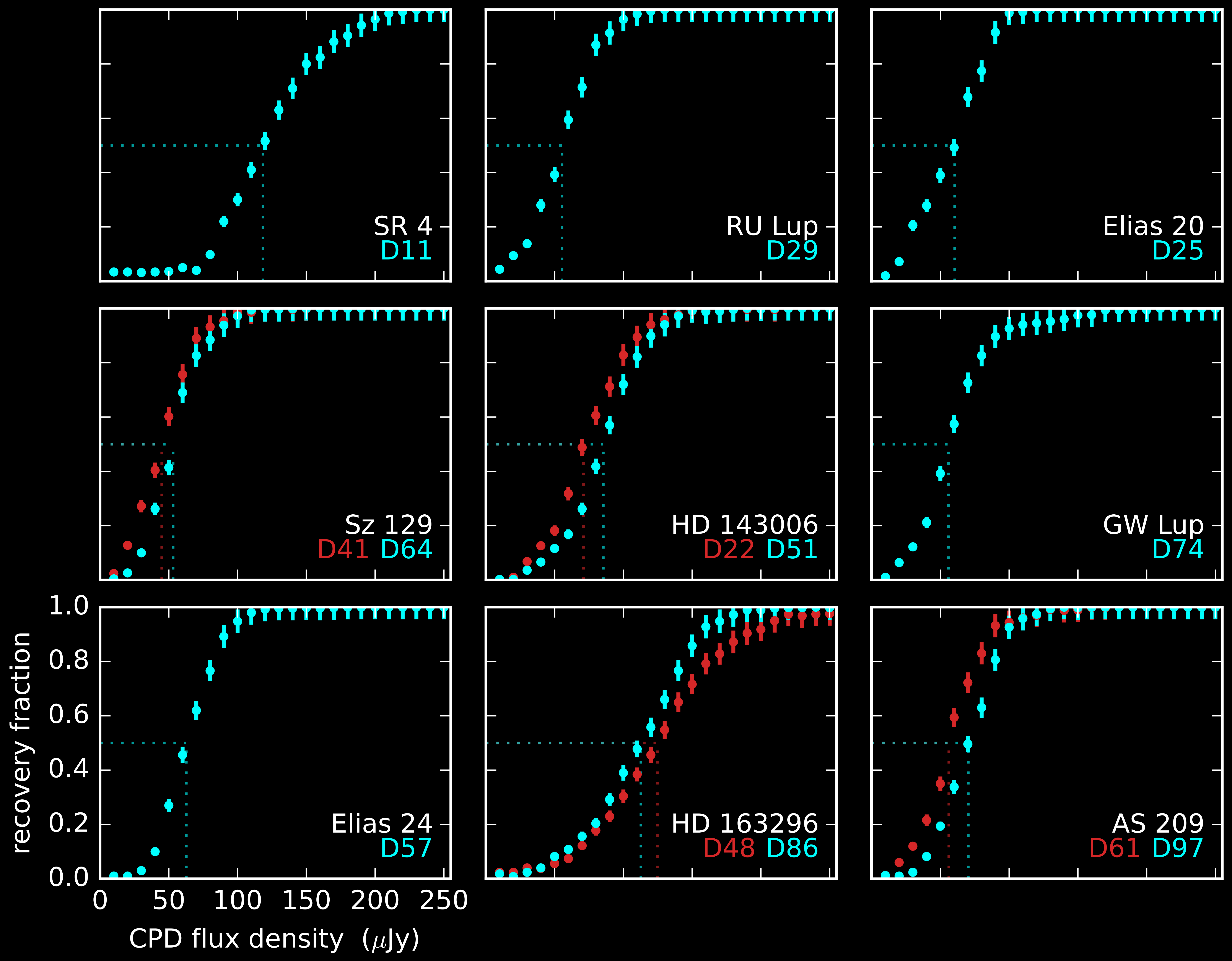
repeat (a lot)

Andrews et al. 2021

(2) quantify CPD sensitivity (injection/recovery tests)

e) define "success" in recovery

f) measure recovery fraction
as fn. of CPD flux



findings!:

no CPDs > 50-70 μJy

(some higher due to asymmetries)

Andrews et al. 2021

What do these "limits" mean?

dust masses < 0.001-0.2 M_{earth}

(for std assumptions, ~Jupiter mass planets)

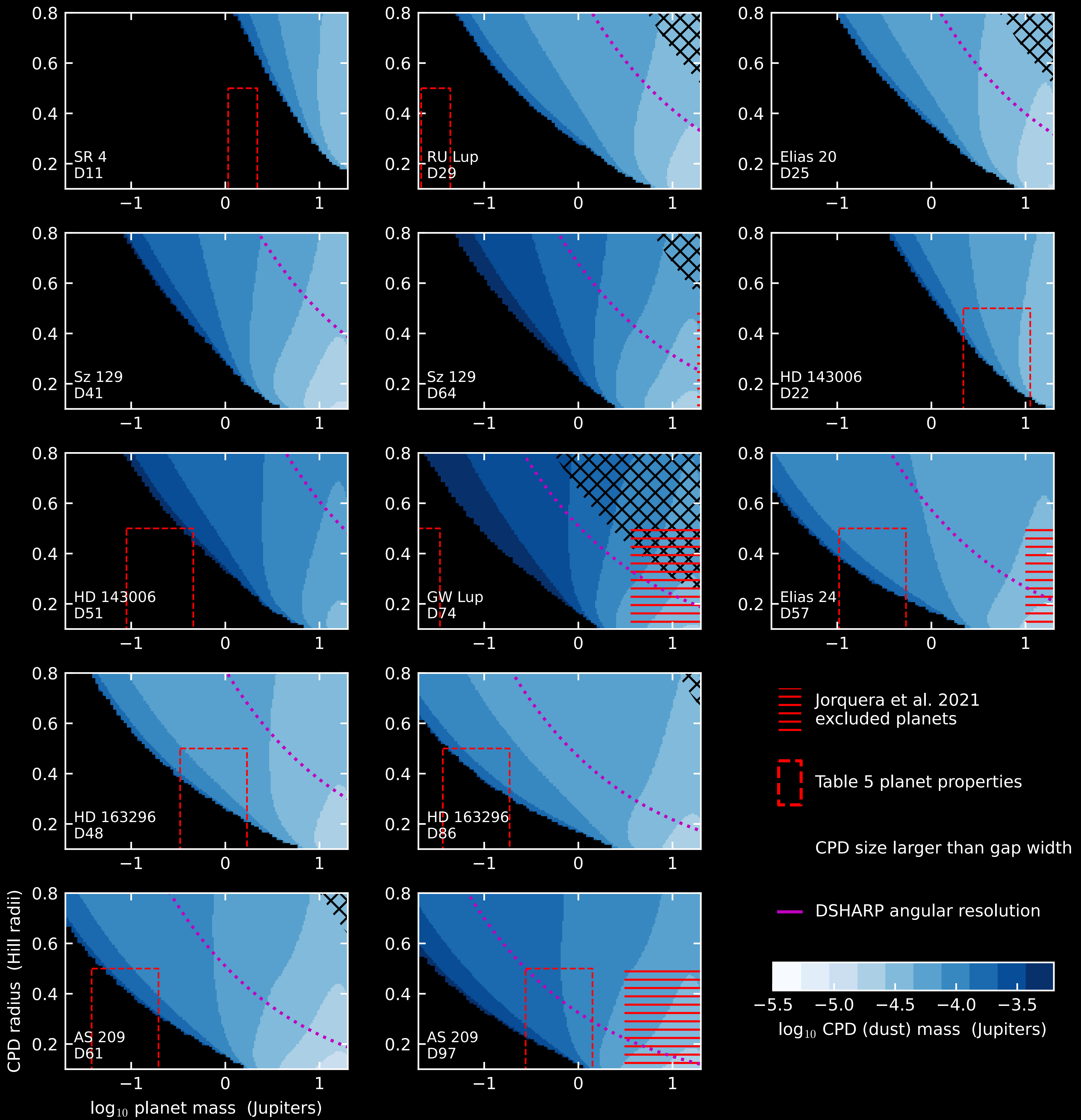
<u>context:</u>

PDS 70c CPD ~ 0.007 M_{earth}

Benisty et al. 2021

Galilean sats. disk ~ 0.07 M_{earth}

e.g., Canup & Ward 2002

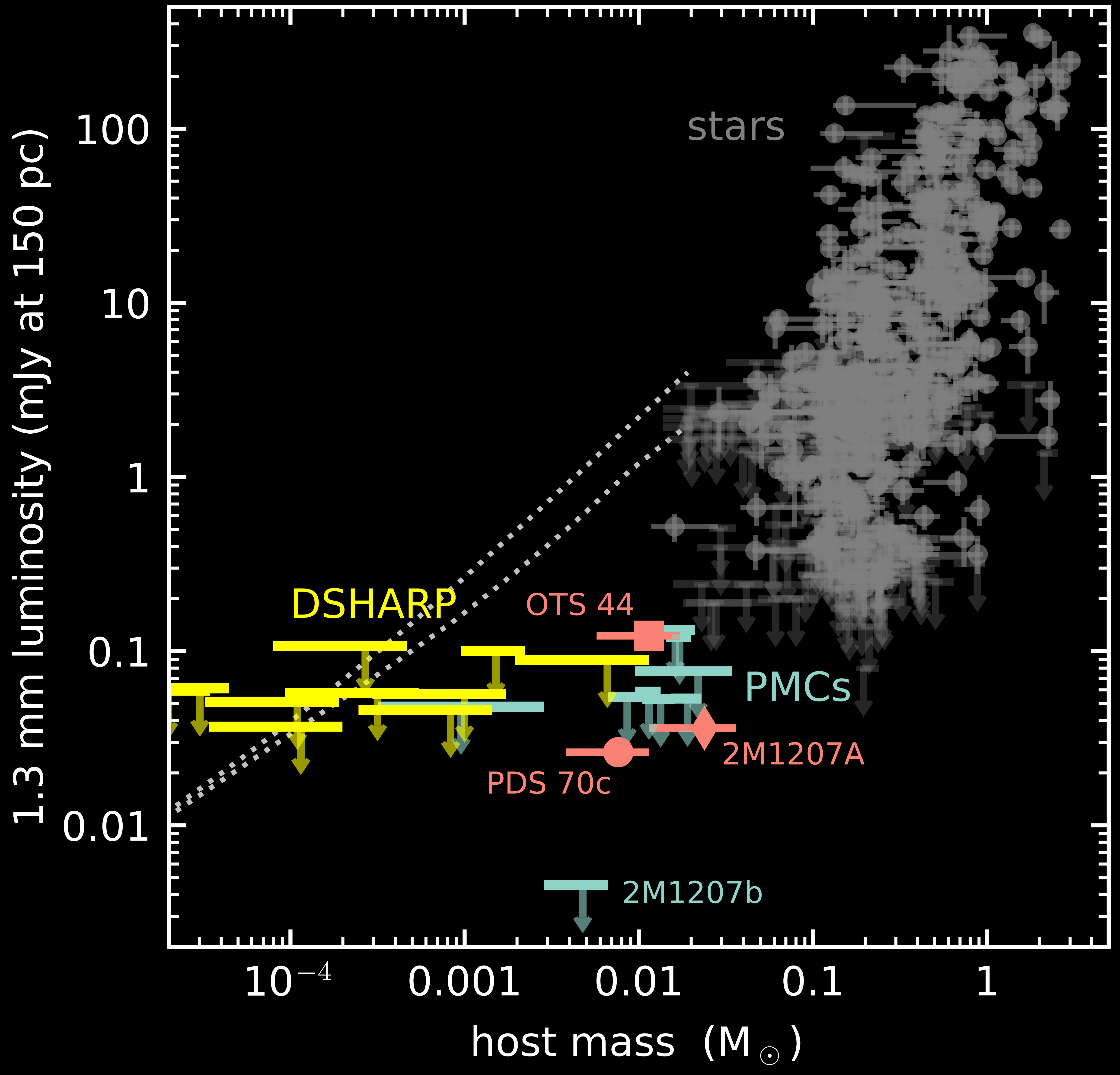


Andrews et al. 2021

more (empirical) context:

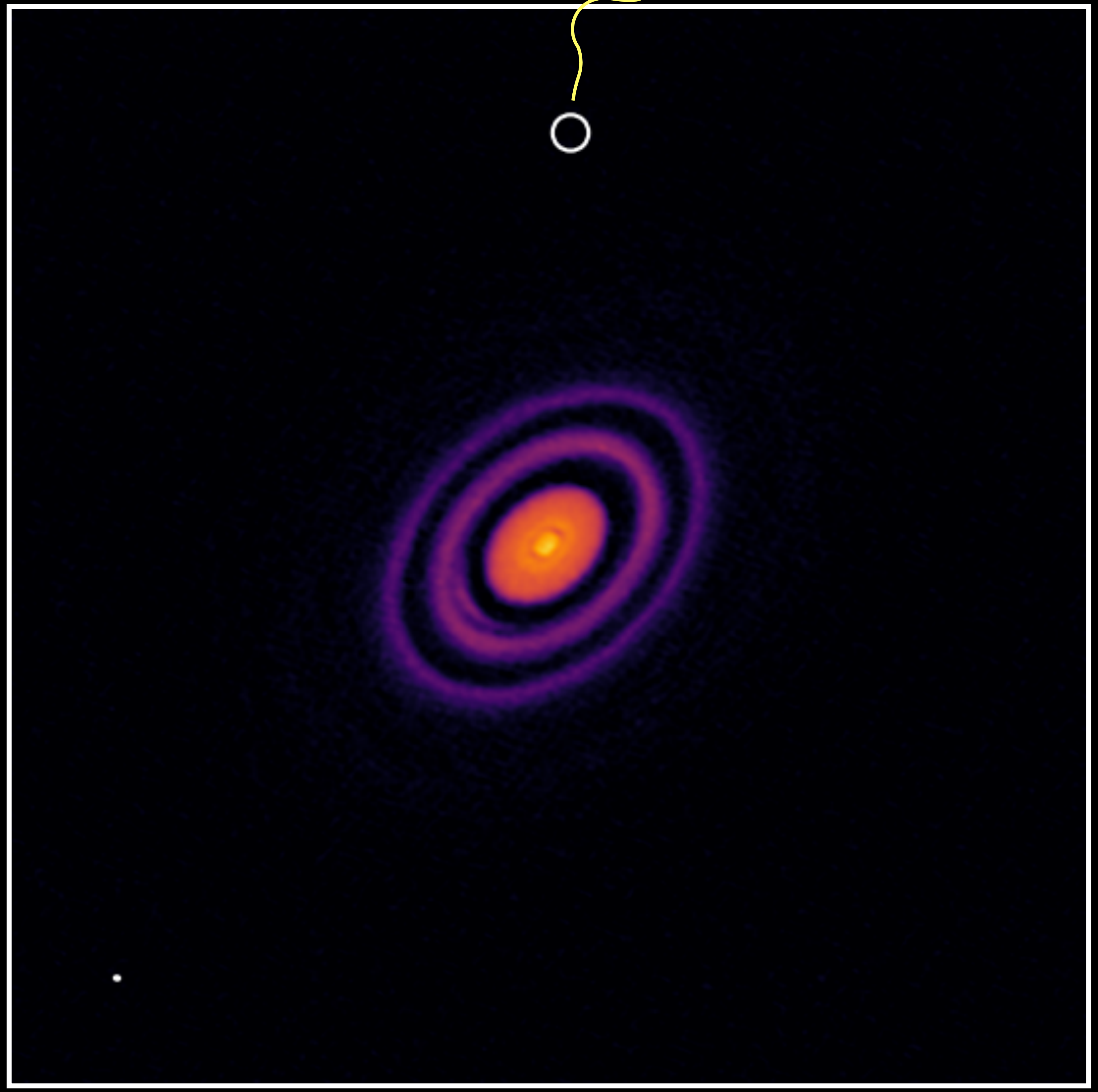
if our interpretation of gap properties is ~right, then

CPDs might be *really* faint!



Andrews et al. 2021

other potential options (… why are you making this so hard?)



Pinte et al. 2018

Andrews et al. 2018; Isella et al. 2018

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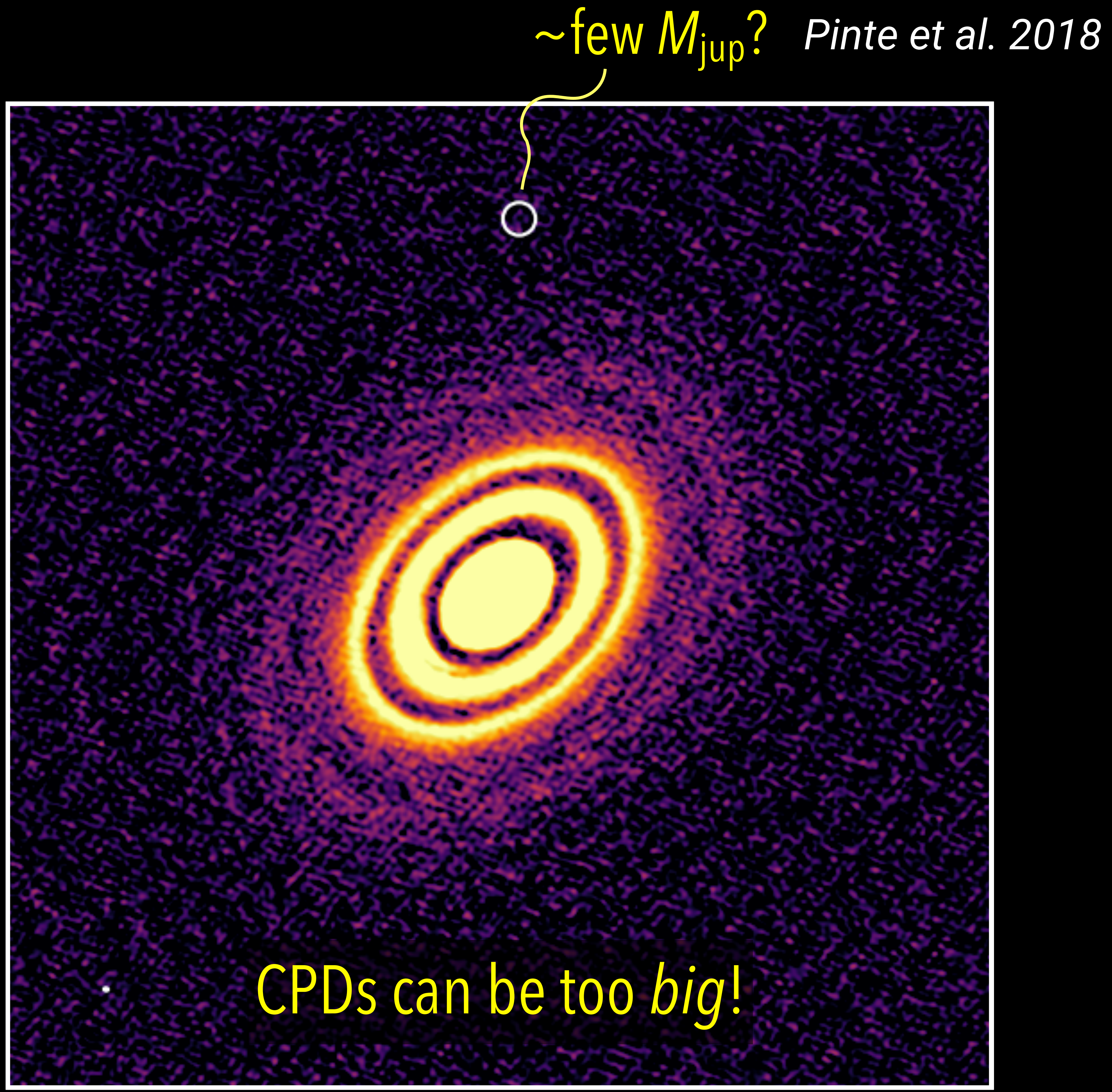

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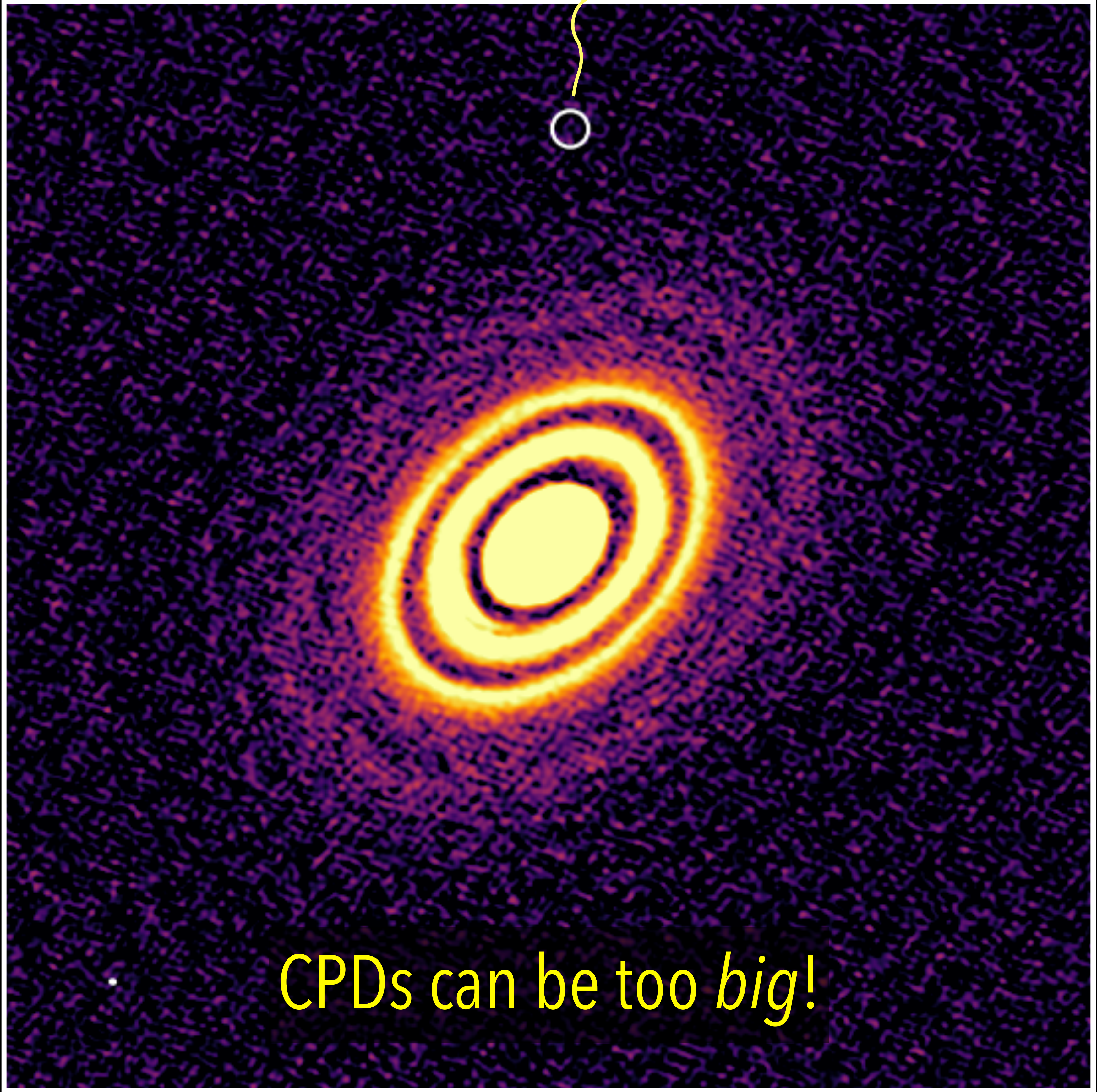

Pinte et al. 2018

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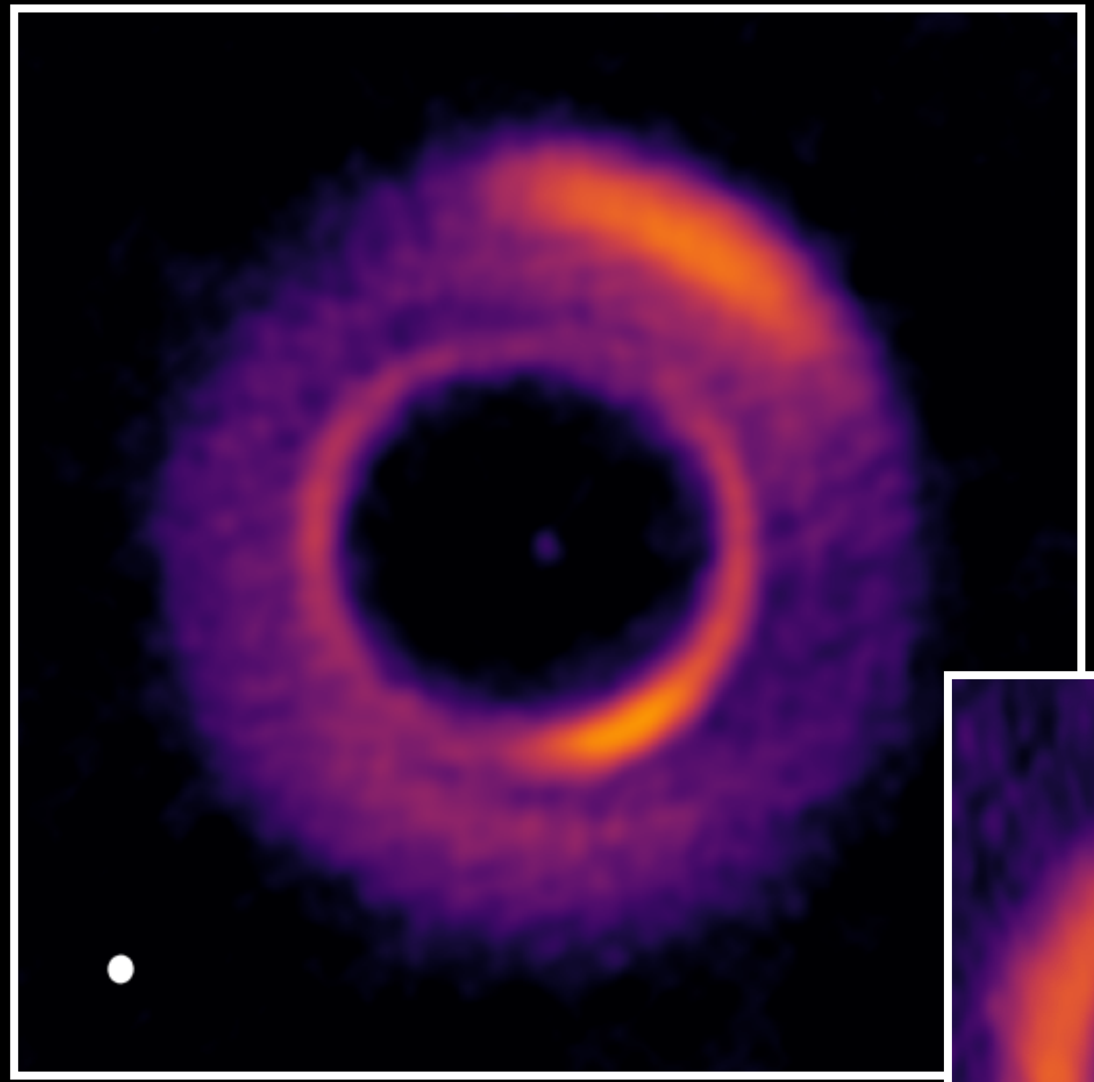
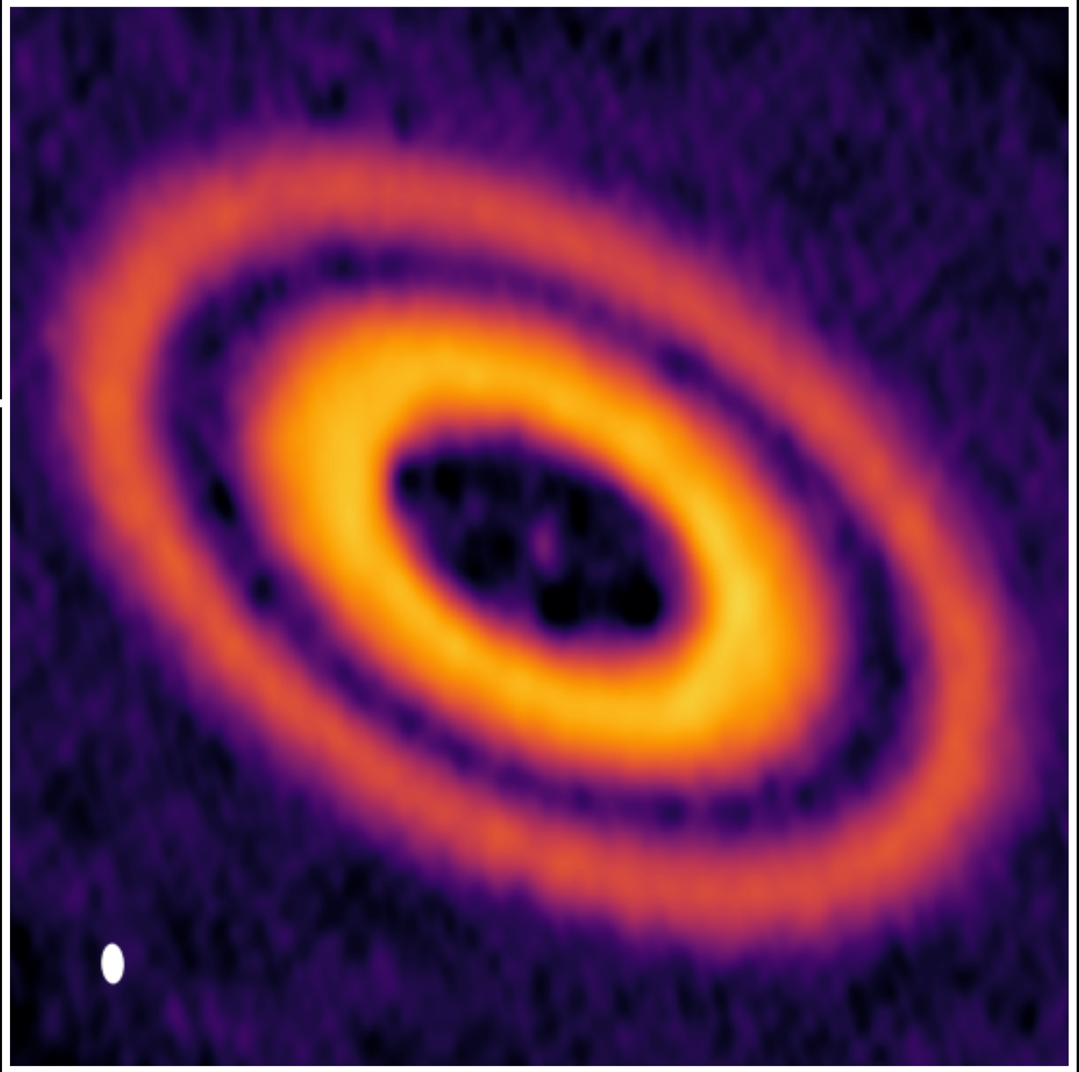


Dong et al. 2018

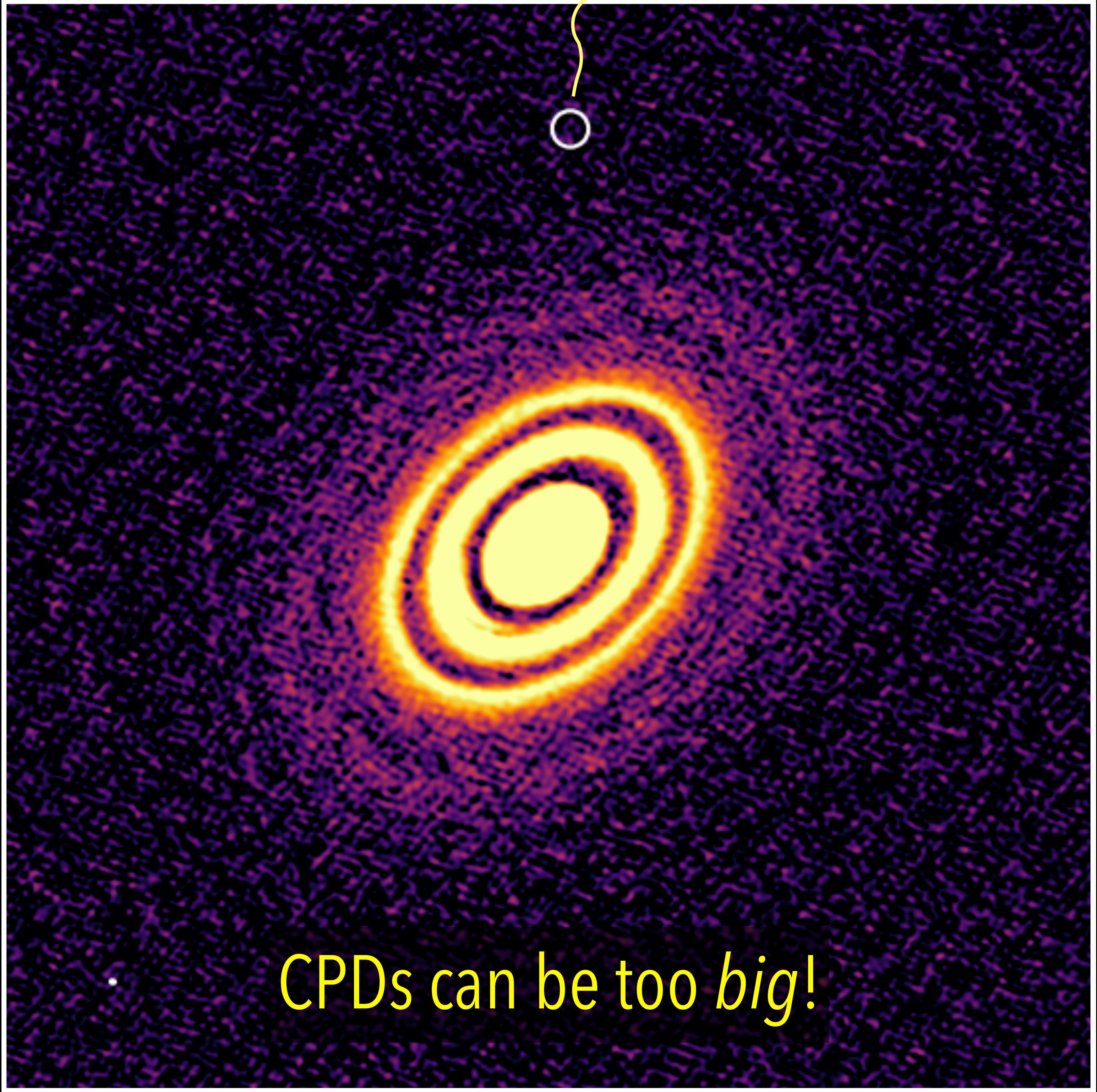


Huang et al. 2020

massive planets might
mean more filtering,
less CPD continuum!

other potential options (… why are you making this so hard?)

~few $M_{\rm jup}$? *Pinte et al. 2018*



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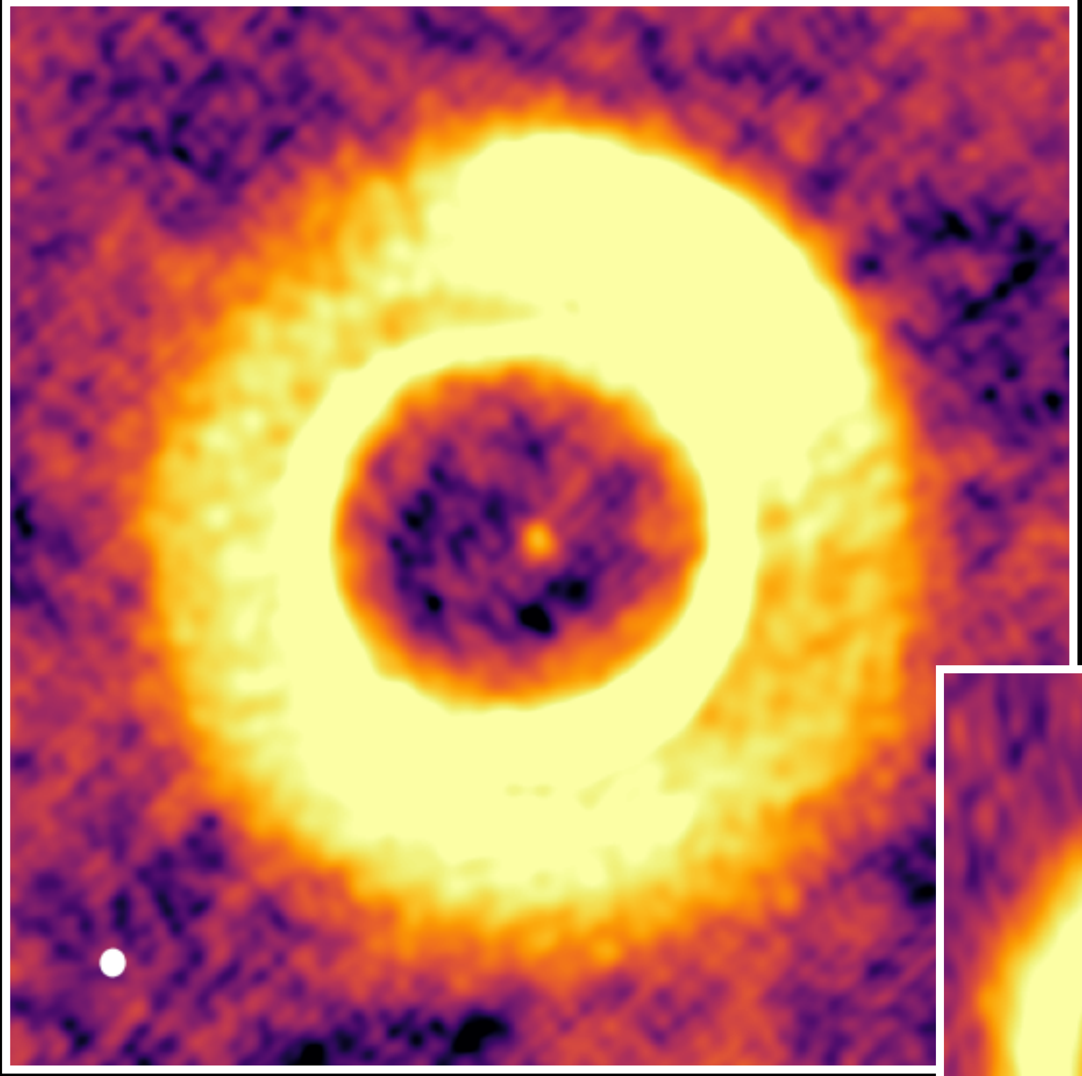
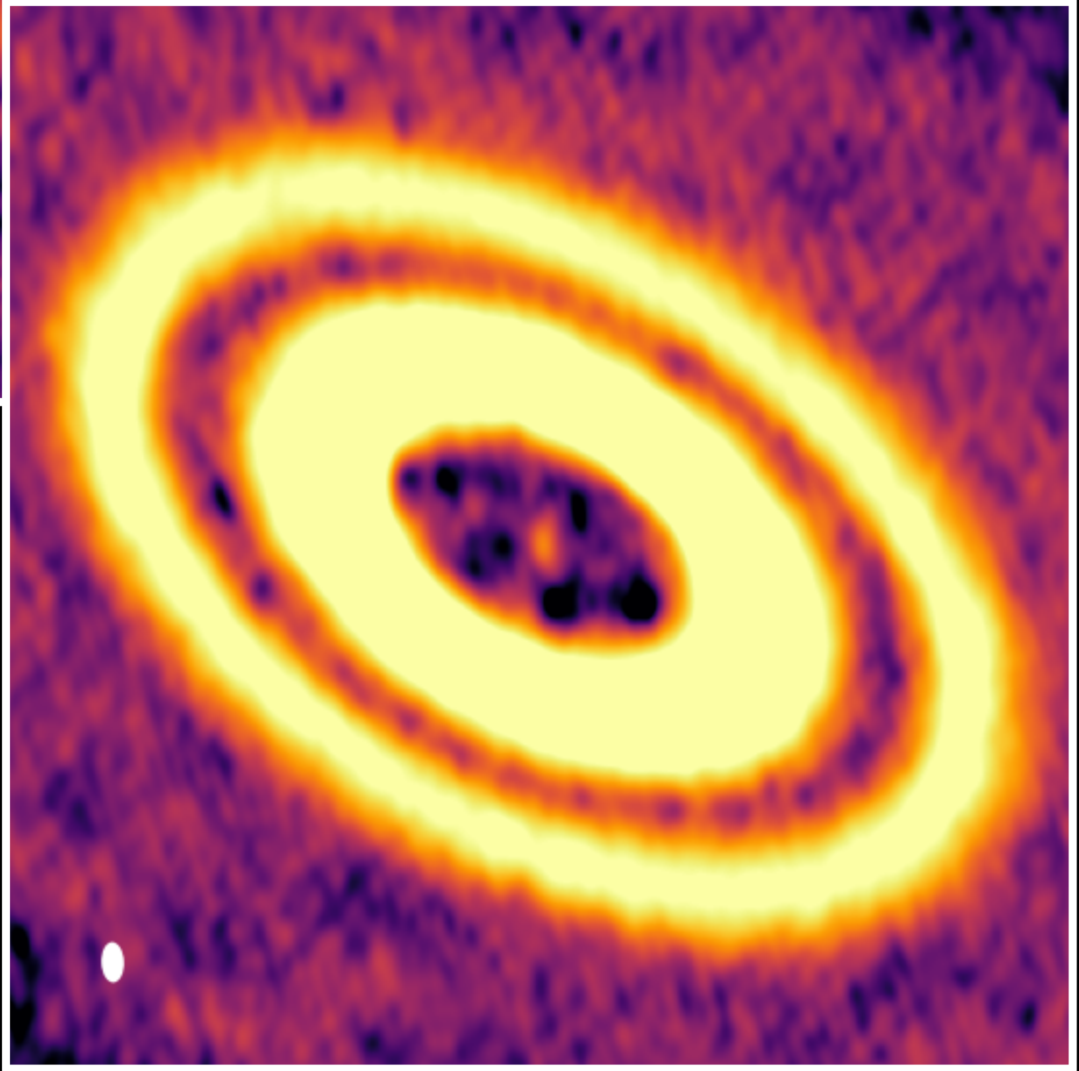


Dong et al. 2018

transition disk cavities can make for a tough imaging problem!

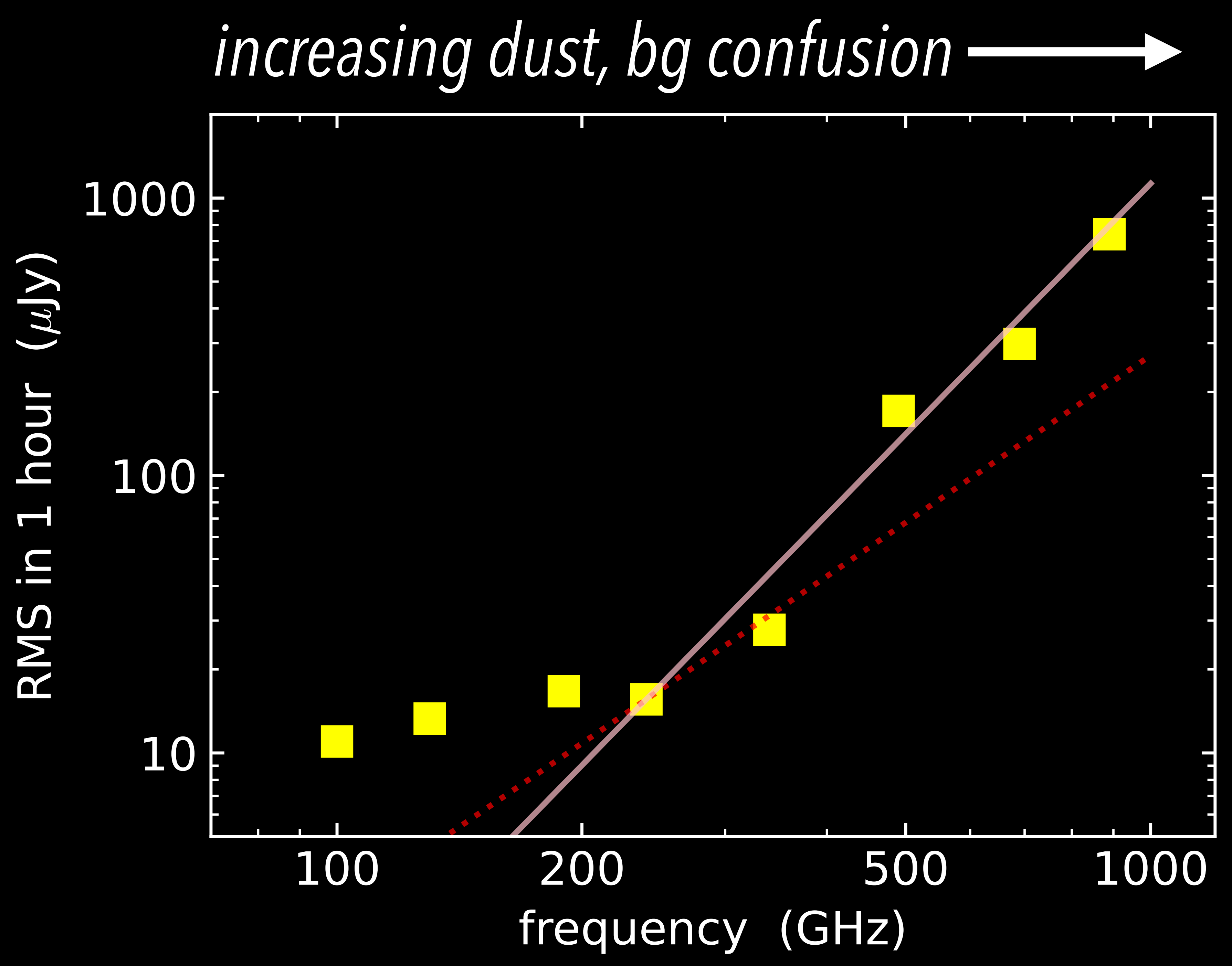


Huang et al. 2020

massive planets might mean more filtering, less CPD continuum!

how can we do better?… hunting for CPDs in the mm continuum

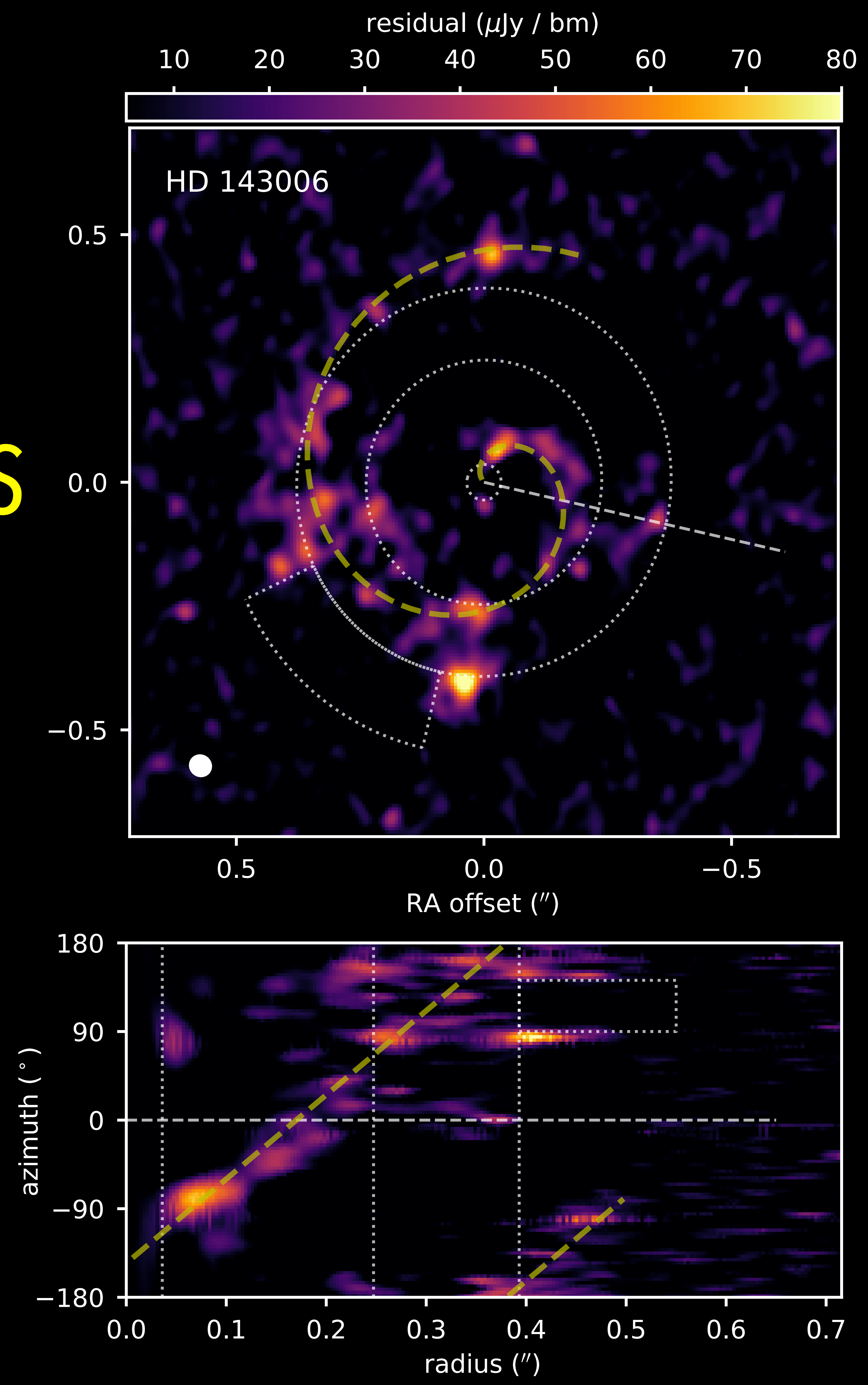
1) better sensitivity



2) asymm. models

3) targeted searches

4) CPD predictions!



Andrews et al. 2021